A Study of Temperature Variation in Upper Ganga Canal Command India

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Abstract

Climate change has affected the climatic parameter characteristics worldwide. Investigations have been carried out by climatologists to find a possible relation of climate change with anthropogenic behavior by studying trends in different climatic parameters. However, the changes are not the same for all regions especially in India due to localized intensity, thus it must be quantified locally to manage the natural resources. Temperature, one of the most important components of climatic parameter, has been widely measured as a starting point towards the apprehension of climate changes courses. The main purpose of this study is to observe the temporal variability of temperature for the period of 1901-2002 (102 years), to improve the hydrological status of Upper Ganga Canal Command located in Uttar Pradesh and Uttarakhand as well as to determine trend in annual mean and monthly Temperature time series using nonparametric methods (i.e. the Mann–Kendall and Sen's Slope tests). The magnitudes of trend in a Temperature time series have been estimated by Sen's estimator method. Auto correlation effect is reduced from the Temperature series before the application of the Mann–Kendall test. On annual basis, the analysis of Mann–Kendall test shows increasing (positive) non-significance trend in temperature time series over Upper Ganga Canal Command. Thus, in the study area, the temperature is increasing, which leads to the increment in evaporation, warmer days and nights in summer.

Keywords

Temperature; Non-Parametric Tests; Trend Analysis; Auto Correlation; Mann–Kendall and Sen's T Tests

Introduction

Concurrence of scientific evidence shows that climate change has begun to manifest itself, globally, in the form of increased downpours and storms, rising temperature and sea level, retreating glaciers, etc. and the Report of Fourth Assessment of the Intergovernmental Panel on Climate Change (IPCC 2007) shows that the global mean surface air temperature increased by 0.74°C while the global mean sea surface temperature (SST) rose by 0.67°C over the last century. In regional context, Kothawale and Rupa Kumar (2005) have shown diurnal asymmetry of temperature trends, indicating that the warming over the India was solely contributed by maximum temperature. Dash et al. (2007) and Dash and Hunt (2007) have emphasized the temporal and spatial changes in temperature and temperature over several regions of India. Goswami et al. (2006) have provided comprehensive analysis of extreme temperature events during Indian monsoon period with increase (decrease) in the frequency and magnitude of extreme (moderate) rain events over central India. Dash et al. (2007) in their recent study have indicated increasing trend in the number of short spell heavy rain elements and decreasing trend in the occurrence of long spell rain events in India. Further, Klein-Tank et al. (2006) have shown changes in the indices of climatic extremes associated with temperature and precipitation over central and south Asia. Analysis of global changes observed in daily climate extremes of temperature and precipitation shows significant changes in temperature extremes associated with warming (Alexander et al. 2006). Over the mountainous regions, such as the Swiss and Polish Alps, the Rockies (Brown et al. 1992; Diaz and Bradley 1997; Beniston et al. 1997; Wibig and Glowicki 2002; Beniston 2003; David et al. 2003; Rebetez 2004) and Andes (Villaba et al. 2003; Vuille et al. 2003) studies have shown significant increase in the surface air temperatures. In the mountainous region of the Himalayas, a limited number of studies in Nepal, covering some parts of the Himalayas and Tibet have also revealed similar trends based on earlier publications (Pant and Borgaonkar 1984; Li and Tang 1986; Seko and Takahashi 1991 and Thompson et

al.2000). Yadav et al. (2004) used tree rings to reconstruct premonsoon temperature records in the western Himalayas and found a decreasing trend during the second half of the 20th century. Kriplani et al. (1996) found that the time series of temperature for the period 1851–1975 over Nepal was characterized with decadal variations but no long-term trends. Also, Kriplani et al. (2003) noted that area covered by spring snow has been declining and snow has been melting faster from winter to spring after mid 1990s over the western Himalayan region based on satellite derived data for the period 1986– 2000. The effects of climatic change and variability have been analyzed by many researchers in the last half-century, because of higher demographic pressure, leading to climatic changes and variability (Gleick, 1993, 2000; Vorosmarty et al., 2000; Shiklomanov and Rodda, 2003; Milliman et al., 2008). The problem is more severe in India and China where population is large and poses continuous threat to the fresh water. Gleick, (2000), reported that these two countries have utilized about 40% of global freshwater for the purpose of irrigation. Some parts of the French Mediterranean area have been studied by Chaouche et al. (2010), which is sensitive to the climate change. The main objective of this study to find out the monotonic trend (both for monthly and annual) of temperature by using Mann-Kendall and Sen's Slope Test so as to know the change and slope in magnitude.

Methodology

Study area

The Upper Ganga Canal (UGC) system, commissioned as far back as in 1854-1855, has its origin from the mythological Ganga River. The Ganga originates from the Gangotri glacier in the Himalayas at an altitude of 7010 M above mean sea level in the Uttarkashi district of Uttraranchal. The river, called Bhagirathi at its source, descending down the valley is joined by the Alaknanda at Dev Prayag; the Bhagirathi Kharak and Satopanth. Confluence with Alakananda, the river is called the Ganga River. In the beginning one of the branches of river-a natural channel flowing near Haridwar-was utilized to divert practically the entire winter flow by construction of temporary obstructions across other branches. This arrangement continued to work for almost fifty long years. With increase in demand, the state of Uttar Pradesh took up construction of permanent headwork in 1913 and completed it in 1920. It consisted of a weir about 550 m length fitted with 1.8 m height falling shutters & located about 3 km upstream of old regulator. The UGC system then comprised 910 km of main canal and branches, and 5280 km of distributaries to provide irrigation facilities in the district of Saharanpur, Muzaffarnagar, Meerut, Bulandshaher & Aligarh. The Upper Ganga Canal takes off from the right flank of Bhimgoda barrage which replaced the old weir at Haridwar in 1991-92. The canal with a head discharge of 190 cumecs (6750 cusecs) presently provides irrigation in a gross command area of about 20 lakh ha in 10 districts of Western Uttar Pradesh. There are 4 major cross drainage works in initial 36 km of the main canal. In the revised proposal, the canal has to carry an increased discharge of 295 cumecs (10419 cusecs). The maximum capacity of the canal in head reaches is proposed to be as 370 cumecs (13068 cusecs) which includes 20% extra inflow for silt ejector. The Ganges or Ganga Canal is a canal system that irrigates the Doab region between the Ganges River and the Yamuna River in India as shown in FIG. 1. The canal is primarily an irrigation canal, although it has been partly also used for navigation, primarily for its construction materials. Separate navigation channels with lock gates were provided on this system for boats to negotiate falls. The Upper Ganges Canal has since been enlarged gradually for the present head discharge of 10,500 ft^3/s (295 m^3/s). The system consists of main canal of 272 miles and about 4000 miles long distribution channels. The canal system irrigates nearly 9,000 km^2 of fertile agricultural land in ten districts of Uttar Pradesh and Uttarakhand. The location of Meteorological station in Upper Ganga Canal Command is as shown in FIG. 2.

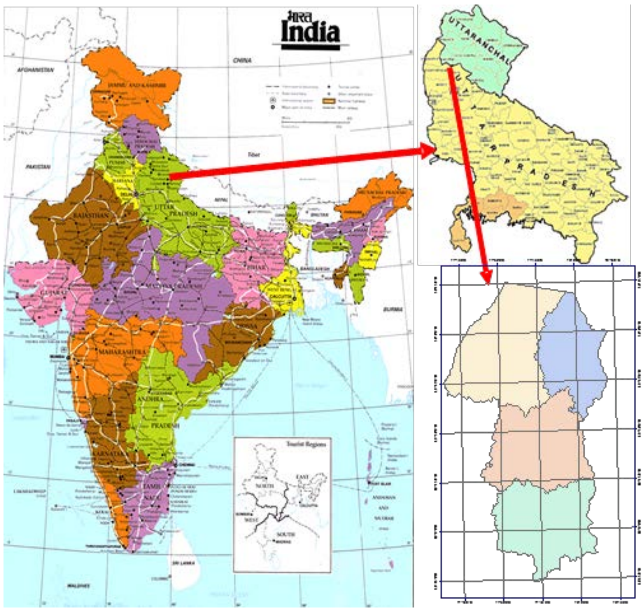

FIGURE 1 LOCATION OF UPPER GANGA CANAL COMMAND AREA

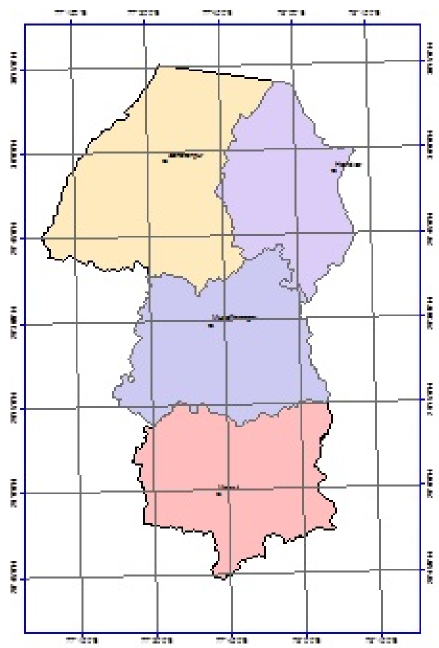

FIGURE 2 LOCATION OF METEOROLOGICAL STATION IN UPPER GANGA CANAL COMMAND

Trend Analysis

In trend, it is necessary to remove the auto correlation effect from the rainfall and temperature time series. If there is a positive auto correlation in the time series, then the non-parametric test will suggest a significant trend in a time series that is, in fact, random more often than specified by the significance level (Kulkarni and Van Storch, 1995).

For this, Von Storch and Navarra (1995) suggested that the time series should be pre-whitened. The Pre-whiting technique is applied to eliminate the effect of serial correlation on the non parametric test.

$$^{pw}x_j = x_j - cx_{i-1} \quad (1)$$

Where, $^{pw}x_j$ is the pre-whitened data to be used in the subsequent trend analysis and c is the lag-1 serial correlation coefficient as determined directly from the data using Equation 1.

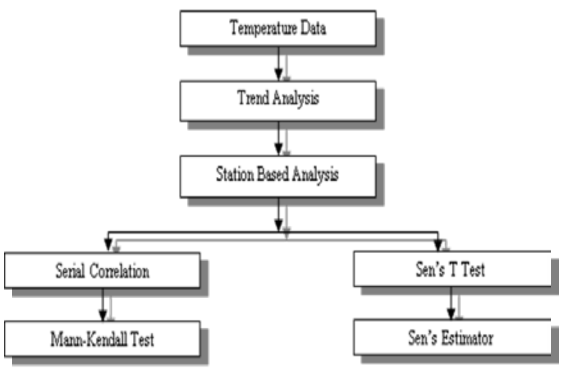

FIGURE 3 PROCEDURES OF ANALYSIS METHODOLOGY USED IN UPPER GANGA CANAL COMMAND AREA

The station based Temperature data downloaded from Indian Water Portal website was analysed to remove the auto correlation effect from the temperature time series so as to know whether the test will be parametric or non-parametric. The procedure flow chart is given in Figure. 3.

1) ***Mann-Kendall Test***

This test, generally known as Kendall's *r* statistic, has been widely used to test randomness against trend in hydrology and climatology. It is a rank-based procedure robust to the influence of extremes and good for use with skewed variables. According to this test, the null hypothesis H_0 states that the deseasonalized data (x_1,…….., xn) is a sample of n independent and identically distributed random variables. The alternative hypothesis H_1 of a two-sided test is that the distributions of x_k and x_j are not identical for all k, $j < n$ with $k = j$. The test statistic S, which has mean zero and a variance computed by Equation (4), is calculated using Equations (2) and (3), and asymptotically normal (Hirsch and Slack, 1984)

$$S = \sum_{k-1}^{n-1} \sum_{j=k+1}^{n} \operatorname{sgn}(x_j - x_k) \quad (2)$$

$$\operatorname{sgn}(x_j - x_k) = \begin{Bmatrix} +1 \text{ if } (x_j - x_k) > 0 \\ 0 \text{ if } (x_j - x_k) = 0 \\ -1 \text{ if } (x_j - x_k) < 0 \end{Bmatrix} \quad (3)$$

$$Var(S) = \left[\frac{n(n-1)(2n+5) - \sum_t t(t-1)(2t+5)}{18} \right] \quad (4)$$

The notation t is the extent of any given tie and denotes the summation over all ties. In cases where the sample size n > 10, the standard normal variety z is computed by using Equation (5) (Douglas *et al.*, 2000). In a two-sided test for trend, H_0 should thus be accepted if $|z| \le z_{1-\alpha/2}$ (here $\alpha = 0.1$) at the level of significance. A positive value of S designates an 'increasing trend'; likewise, a negative designates 'descending trend'

$$Z = \begin{Bmatrix} \dfrac{S-1}{\sqrt{Var(S)}} & \text{if} & S > 0 \\ 0 & \text{if} & S = 0 \\ \dfrac{S+1}{\sqrt{Var(S)}} & \text{if} & S < 0 \end{Bmatrix} \quad (5)$$

2) ***SEN'S Slope Estimator.***

The magnitude of trend is estimated with the help

of Sen's estimator. In this case, linear trend is present and hence the true slope is estimated by this method. Here, the slope (T_i) of all data pairs is first computed as *(Sen, 1968)*

$$T_i = \frac{x_j - x_k}{j - k} \text{ for i = 1,2,……..,N} \qquad (6)$$

In which x_j and x_k are represented as data values at time j and k (j>k) correspondingly. The median of these N values of T_i is considered as Sen's estimator of slope which is given as

$$Qi = \begin{cases} T_{\frac{N+1}{2}} & N \text{ is odd} \\ \frac{1}{2}\left(T_{\frac{N}{2}} + T_{\frac{N+2}{2}}\right) & N \text{ is even} \end{cases} \qquad (7)$$

Sen's estimator is calculated as Q_i=T(N+1)/2 if N is odd, and computed as Q_i=[$T_{N/2}$+$T_{(N+2)/2}$]/2 if N is even. Lastly Q_i is estimated by a two sided test at 100 (1-α)% confidence interval and then a true slope can be derived by the non-parametric test Q_i with a positive value indicating an upward or increasing trend and a negative value of Q_i which signifies a downward or decreasing trend in the time series.

Results

Trend analysis of temperature for the period of 1901-2002 (102 years) in Upper Ganga Canal Command located in Uttar Pradesh and Uttarakhand has been done in the present study. Mann-Kendall and Sen's Slope Estimator have been used for the determination of the temperature trend detection. Initially, values of Serial correlation coefficient after pre-whiting the temperature series for 1901-2002 (102 years) of all the four station are given in TABLE 1 with their latitudes and longitudes.

Temperature Trend in Upper Ganga Canal Command region is presented station wise (1901-2010) namely: *Haridwar, Meerut, Muzaffarnagar, Saharanpur* (TABLE 2 and FIG. 4).

TABLE 1 VALUES OF SERIAL CORRELATION COEFFICIENT AFTER PRE-WHITING THE TEMPERATURE SERIES

Stations	Latitude	Longitude	Annual	Pre-monsoon (Mar-May)	Monsoon (June-Sept)	Post monsoon (Oct-Nov)	Winter (Dec-Feb)
Haridwar	29.9639	78.1732	0.056934	0.014214	0.109359063	0.152539	0.002727
Meerut	28.9845	77.7064	0.041107	0.003844	0.044517169	0.105898	0.002727
Muzaffarnagar	29.4667	77.6833	0.047127	0.010277	0.082102474	0.119504	0.002727
Saharanpur	30.6167	77.9167	0.055188	0.019206	0.122944437	0.13909	0.002727

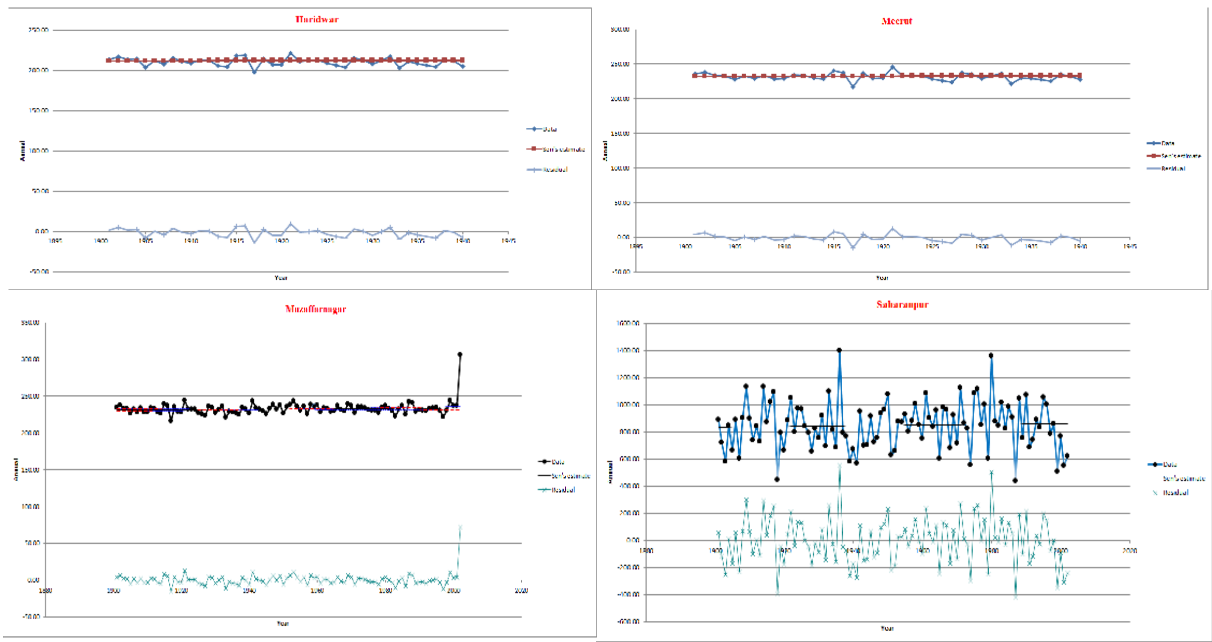

FIGURE 4 ANNUAL TEMPERATURE TREND GRAPH PRESENTED STATION WISE IN UPPER GANGA CANAL COMMAND REGION

TABLE 2 TEMPERATURE TREND IN UPPER GANGA CANAL COMMAND REGION IS PRESENTED STATION WISE (1901-2010)

Time series	Haridwar			Saharanpur			Muzaffarnagar			Meerut		
	Test Z	Signific.	Q	Test Z	Signific.	Q	Test Z	Signific.	Q	Test Z	Signific.	Q
JAN	1.49		0.007	-0.81		-0.041	1.46		0.006	1.48		0.005
FEB	2.90	**	0.014	0.47		0.023	3.01	**	0.014	3.12	**	0.014
MAR	1.42		0.008	1.54		0.051	1.39		0.008	1.38		0.007
APR	1.59		0.009	0.21		0.005	1.87	+	0.010	1.87	+	0.010
MAY	0.50		0.002	1.54		0.068	0.42		0.002	0.27		0.001
JUN	-1.50		-0.007	0.70		0.103	-1.82	+	-0.008	-2.06	*	-0.009
JUL	-2.76	**	-0.008	0.53		0.140	-2.53	*	-0.008	-2.17	*	-0.007
AUG	-1.38		-0.003	-0.17		-0.039	-1.27		-0.003	-0.72		-0.002
SEP	-2.30	*	-0.006	0.07		0.017	-2.34	*	-0.006	-1.93	+	-0.006
OCT	0.13		0.000	0.28		0.009	-0.16		0.000	0.20		0.001
NOV	1.94	+	0.006	0.17		0.000	2.19	*	0.007	2.49	*	0.007
DEC	2.84	**	0.010	-0.20		-0.003	3.58	***	0.010	3.74	***	0.011
Annual	1.11		0.022	0.35		0.257	1.45		0.028	1.82	+	0.031
Pre-monsoon (Mar-May)	1.68	+	0.019	2.24	*	0.144	1.93	+	0.021	1.87	+	0.019
Monsoon (June-Sept)	-2.68	**	-0.020	0.14		0.097	-3.50	***	-0.025	-3.26	**	-0.024
Post-monsoon (Oct-Nov)	1.35		0.006	0.25		0.008	1.52		0.007	1.89	+	0.009
Winter (Dec-Feb)	4.04	***	0.032	0.10		0.008	4.43	***	0.030	4.46	***	0.031

Note: *** if trend at $\alpha = 0.001$ level of significance
** if trend at $\alpha = 0.01$ level of significance
* if trend at $\alpha = 0.05$ level of significance
+ if trend at $\alpha = 0.1$ level of significance

Trend analysis of four cities represents almost same trend in temperature excepts Saharanpur. It is observed that a reverse trend is found in month of monsoon. Temperature is decreasing in these months instead of increasing. But in Pre-monsoon, post-monsoon and in winter temperature have increasing trend. Temperature variation also depends upon location of city. Decreasing trend in monsoon is also due to uneven distribution of rainfall in monsoon. Because it is clear that in summers temperature is increasing. The higher temperature means more evaporation and rainfall with uneven distribution. This will result in flood and extreme conditions of climate. However, this changing trend affects cities which are not in the way of easterly monsoon like Saharanpur. This receives less rainfall in two seasons in month of December and January from northerly cyclones which mostly come from black sea.

If comparison is made between Haridwar with Saharanpur, it can be seen that variation of monsoon for Haridwar is between -2.30 to -1.50 but in Saharanpur it is 0.70 to 0.07. Overall trend for Pre-Monsoon is increasing in Saharanpur 2.24 which is maximum. Meerut has maximum increasing trend of 4.46 for winter session. Muzaffarnagar has decreasing trend of -3.50 which is maximum among other three cities. It can be noted that earth is passing from intermediate zone of climate change. If this trend continues for more hundred years, climate will try to reset its eco-balance system, resulting in flood, drought and forest fire etc. This means the longest summer and the shortest winter session. Trend data represent very less change in variation in month of October, and for Haridwar it is 0.13 and for Muzaffarnagar it is only -0.16.

Conclusion

The study has analyzed the temperature data of 102 years from 1901 to 2002 to determine the trend of temperature in the Upper Ganga Canal Command region. As this region is rapidly growing, any change in the temperature trend pattern may have considerable impact on human life in this region. The Z Test value of MK Test for annual is 1.11 for Haridwar, 0.35 for Saharanpur, 1.45 for Muzaffarnagar and 1.82 for Meerut, showing increasing trend in

temperature, therefore, it can be concluded that there may be an impact of climate change in present, which contributes to the prolonged and heavy temperature that is rising with time. Similarly, Sen's Slope has also estimated increasing magnitude of slope for temperature data. This study has also revealed that the monotonic trend (annual) for temperature time series found to be increasing (positive) with level of non-significance trend.

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